P7.7   IMPROVED DETECTION OF WSR-88D MESOCYCLONE SIGNATURES
              DURING THE OKLAHOMA TORNADO OUTBREAK OF 3 MAY 1999

Vincent T. Wood and Rodger A. Brown
National Severe Storms Laboratory
Norman, Oklahoma 73069

1. INTRODUCTION

Using a mesocyclone model and a simulated WSR-88D Doppler radar, the recent studies of Wood et al. (2000) have shown that a stronger mesocyclone signature at long range is produced using 0.5^o azimuthal sampling instead of conventional 1.0^o sampling. The 0.5^o azimuthal sampling is produced by using half as many transmitted and received pulses as for 1.0^o sampling. Two reasons for producing the stronger signature are (a) the effective beamwidth resulting from 0.5^o azimuthal sampling is narrower than that for 1.0^o azimuthal sampling, and (b) with twice the azimuthal density of data points, there is better sampling of the peaks of the mesocyclone signature. This improvement could be realized in WSR-88D detection of mesocyclones at long range by decreasing the azimuthal sampling interval from 1.0^o to 0.5^o.

The purpose of this paper is to verify the Wood et al. findings. Archive Level I (time-series) data were collected at the WSR-88D Operational Support Facility's KCRI radar site in Norman during the tornado outbreak of 3 May 1999. With time-series data, two Archive Level II data tapes were produced - one having 0.5^o azimuthal data collection and the other having 1.0^o azimuthal data collection. These data were used to compare the strengths of 0.5^o azimuthal resolution mesocyclone signatures with the strengths evident from conventional WSR-88D data having 1.0^o azimuthal resolution.

2. APPROACH

Archive I data collected during the tornado outbreak of 3 May 1999 were used to produce an Archive II data set having 0.5^o and 1.0^o azimuthal resolution. During any data collection mode, a WSR-88D radar transmits and receives about 1000 pulses per second. If the antenna were rotating about 25° per second, then about 40 pulses were transmitted and received during the time it took the antenna to rotate 1.0^o. The frequency shifts received from each set of 40 pulses were processed in real-time to produce a mean Doppler velocity value at 1.0^o increments. One way to produce

data at 0.5^o intervals was to average 20 instead of 40 pulses while maintaining the usual antenna rotation rate.

Software developed by the National Center for Atmospheric Research was used to record the basic pulse-by-pulse time-series (Archive Level I) data. After running a few short tests to become familiar with the time-series recording equipment, the first full-fledged data recording data took place on 3 May 1999. Being interested in mesocyclone and tornadic vortex signatures at lower altitudes for this "test case", data were recorded at elevation angles between 0.5^o and 2.0^o for six hours. Data from some mesocyclones on 3 May 1999 were not collected due to Archive I recorder malfunctions.

3. DISCUSSION AND RESULTS

Figure 1 presents a comparison of simulated 1.0^o and 0.5^o azimuthal resolution mesocyclone signatures (black dots) in an azimuthal cross-section through a model mesocyclone. Model peak velocity values are located across the core diameter (pointed curve), while noise-free radar measurements fall along the curve with rounded peaks.

As indicated in Fig. 1, one of the advantages of 0.5^o azimuthal data collection is that the 0.5^o curve is less degraded relative to model peak velocity (pointed curve). This means that a stronger mesocyclone signature is produced with 0.5^o azimuthal sampling. Another advantage is that there are twice as many data points available with which to define the peaks of the mesocyclone signature curve.

From one radar scan to the next, the radar data points can be located at different positions relative to the peaks of the Doppler velocity curves. In order to represent the inherent variability, Doppler velocity signatures were computed for all possible azimuthal placements of 1.0^o and 0.5^o radar data. Furthermore, Gaussian-distributed random noise was added to the extreme data points before deduced mean rotational velocity values were computed. [Note that the deduced mean rotational velocity is one half the difference between the extreme positive and negative Doppler velocity values in the mesocyclone signature (Wood et al. 2000).] The frequency distributions of values for 1.0^o and 0.5^o azimuthal data collection at 100, 150, and 200 km from the radar are presented in Fig. 2.

The distributions in Fig. 2 reveal that there is less variation (i.e., a smaller standard deviation) among the

_____

Corresponding author address: Vincent T. Wood, 1313 Halley Circle, Norman, OK 73069, E-mail: wood@nssl.noaa.gov

various estimates of the mean rotational velocity with 0.5° azimuthal sampling. With increasing range, overall average values of the two mean rotational velocity distributions (indicated by vertical dotted lines in Fig. 2) become farther apart, e.g., the difference increasing from 1.80 m s^{-1} at 100 km to 2.28 m s^{-1} at 150 km to 2.61 m s^{-1} at 200 km. Only a small fraction of the possible mean rotational velocity values with the two distributions actually overlap. The percentage of 0.5° mean rotational velocities that are larger than all of the 1.0° velocities are 77%, 87%, and 86% at 100, 150, and 200 km, respectively. This means that, at least for the average-sized mesocyclone, there are distinct advantages to using an azimuthal sampling interval of 0.5°.
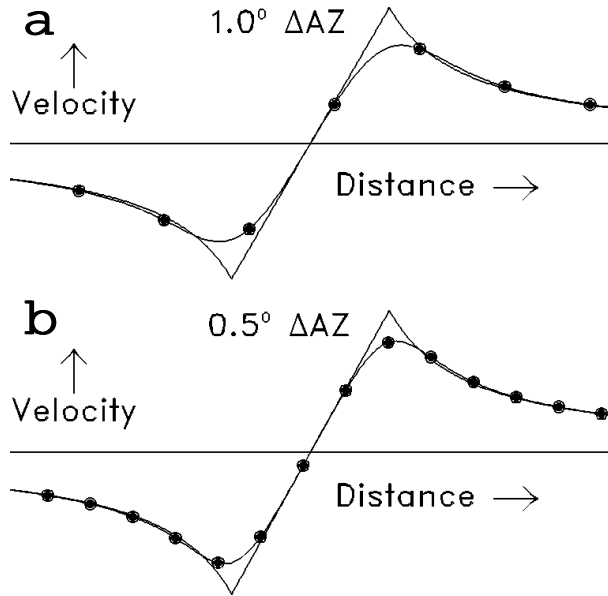

Fig. 1. Relationships of data points relative to the azimuthal profiles of a model mesocyclone for azimuthal sampling intervals (ΔAZ) of (a) = 1.0° and (b) = 0.5° The curve with rounded peaks (along which the data points fall) represents the Doppler-velocity azimuthal profile of the meso-cyclone signature if the radar were able to make measurements in a continuous manner across the mesocyclone at a range of 150 km. Data points (black dots) represent the locations of successive Doppler velocity measurements collected at (a) 1.0° and 0.5° ΔAZ as the radar beam scans across the meso-cyclone. The model azimuthal profile is indicated by the curve with pointed peaks corresponding to the typical mesocyclone having a peak tangential velocity of 25 m s^{-1} at a core diameter of 5 km. (After Wood et al. 2000.)

Figure 3 presents the simulated ratios (curves) of velocity for 0.5° azimuthal sampling ($V_{0.5}$) to velocity for 1.0° azimuthal sampling ($V_{1.0}$) for given values of the mean rotational velocities of nine simulated mesocyclone sizes and strengths. The ratios increase

with range more rapidly for smaller mesocyclones than for larger ones, regardless of mesocyclone strength. It is evident that 0.5° azimuthal sampling is more advantageous over 1.0° azimuthal sampling because the 0.5° azimuthal sampling does a better job in sampling of the peaks of the mesocyclone signature with twice the azimuthal density of data points.
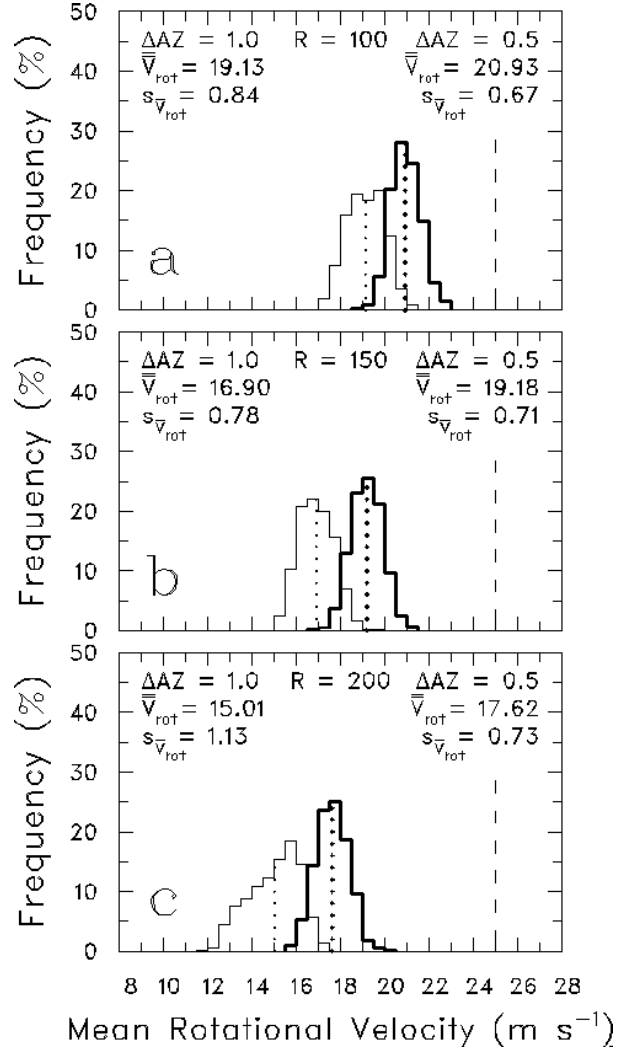

Fig. 2. Frequency distributions of mesocyclone mean rotational velocity estimates at (a) 100, (b) 150, and (c) 200 km range. The thin (thick) lines and thin (thick) vertical dotted lines correspond to the 1.0° (0.5°) azimuthal data collection. The average of the mean rotational velocities ($\overline{\overline{V}}_{rot}$) is indicated by the vertical dotted line. The vertical dashed line represents the peak tangential velocity of the model mesocyclone (same parameter as in Fig. 1). The standard deviation of mean rotational velocity is given by $s_{\overline{V}_{rot}}$ (m s^{-1}). (After Wood et al.)

The strengths of 0.5° azimuthal resolution meso-

cyclone signatures were compared with the strengths evident from conventional 1.0° azimuthal resolution. As shown in Fig. 3, X's represent the actual ratios of mesocyclone velocity signatures of 3 May 1999 for 0.5° and 1.0° data collection. The X's are enclosed within the distribution extremes (long-short dashes). Based on the frequency distributions (e.g., Fig. 2), the distribution minimum is calculated as $C_{0.5}/D_{1.0}$, where $C_{0.5}$ is the minimum distribution velocity of the largest and strongest mesocyclone signature at 0.5° azimuthal sampling, and $D_{1.0}$ is the maximum distribution velocity of that signature at 1.0° azimuthal sampling. Likewise, the distribution maximum is computed as $B_{0.5}/A_{1.0}$, where $A_{1.0}$ is the minimum distribution velocity of the smallest and weakest mesocyclone signature at 1.0° azimuthal sampling, and $B_{0.5}$ is the maximum distribution velocity of that signature at 0.5° azimuthal sampling. This preliminary sample confirms improved mesocyclone detection with 0.5° azimuthal sampling reported in the Wood et al. (2000) study.

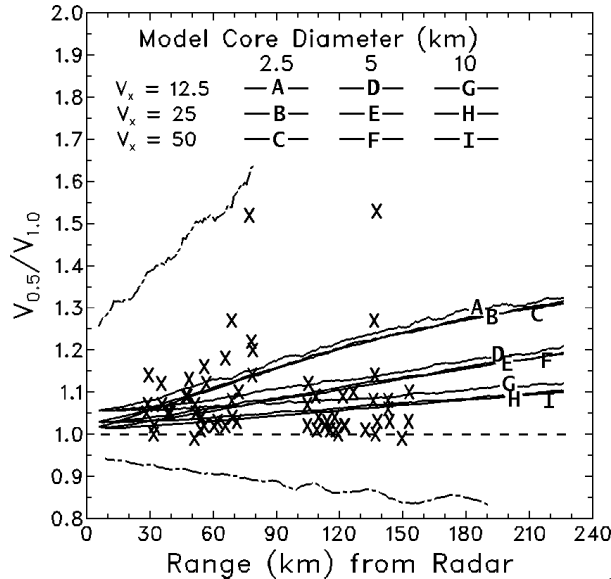*Fig. 3. Ratios of velocity $V_{0.5}$ at 0.5° azimuthal data collection to velocity $V_{1.0}$ at 1.0° azimuthal data collection for given values of the mean rotational velocities of nine simulated mesocyclone strengths and sizes. The long-short dashes represent distribution extremes. The curves have been smoothed using a nine-point running mean. Horizontal dashed line indicates no improvement between $V_{0.5}$ and $V_{1.0}$. Superimposed X's represent the actual ratios of mesocyclone velocity signatures of 3 May 1999 for 0.5° and 1.0° data collection.*

To keep these results in perspective, it is important to remember that beyond a range of about 160 km, the WSR-88D's lowest elevation angle (0.5°) is greater than 3 km above the radar. At these ranges, only the mid-altitude portion of the mesocyclone is detectable. Even

though low-altitude mesocyclone data are not available, the mid-level mesocyclone signature will be stronger and be detectable at much greater ranges for 0.5° azimuthal sampling.

4. SUMMARY

The strengths of 0.5° azimuthal resolution mesocyclone signatures were examined and compared with the strengths evident from conventional WSR-88D data having 1.0° azimuthal resolution. The preliminary studies have shown that a stronger mesocyclone signature is produced using 0.5° azimuthal sampling because (a) there is less smearing/degradation of peak velocities for 0.5° azimuthal sampling than that for 1.0° azimuthal sampling, and (b) with twice the azimuthal density of data points, there is better sampling of the peaks of the mesocyclone signature.

5. ACKNOWLEDGMENTS

6. REFERENCES

Wood, V. T., R. A. Brown, and D. Sirmans, 2000: Technique for improving detection of WSR-88D mesocyclone signatures by increasing angular sampling. *Wea. Forecasting.* (In press.)